

JOURNAL OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.
VOL. XVIII., 1931-32.

10.—AN ECOLOGICAL ANALYSIS OF THE PLANT COMMUNITIES
OF THE "JARRAH" REGION OCCURRING ON A SMALL
AREA NEAR DARLINGTON.

With Special Reference to the Indicator Value of Species.

By R. F. WILLIAMS, B.Sc. (Hons.).

Read 10th May, 1932. Published 23rd June, 1932.

In a paper on "The geology and physiography of parts of the Darling Range near Perth" (2) E. de C. Clarke and F. A. Williams state that they made use of the predominance of a white-barked eucalypt (*E. redunca* var. *elata*) as an indicator of the presence of epidiorite dykes. The original purpose of the present investigation was to verify this observation and to see if there were any reliable indicator plants among the shrub species.

As the work proceeded, however, it was found that interest in the plant communities increased considerably and that the determination of indicator value tended to become more or less subordinate. In this paper an attempt has been made to analyse, by means of quantitative field methods, the composition of the valley vegetation and to compare it with the adjacent vegetation of the hill-tops. Emphasis has also been laid on the correlation between the vegetation units and the more obvious soil-types as derived from the geological formations.

It was decided that the best method of approach to the problem was that of taking a representative area and working out the details as accurately and fully as time would permit. In the choice, care was taken to avoid subseral areas produced by fire and at the same time to have represented all the main soil-types of the Darlington Area. The area finally chosen is included in the University Geology Department's survey of the Darlington Area, and this in turn falls just within the northern limits of the "Jarrah" Region (1, p. 121) and in what Gardner has termed the "Marginal Forest of the Plateau" (4).

METHODS OF WORK.

The area studied was first covered by an accurate topographic survey (by the method of tacheometry) and the positions of most of the trees were determined as the work progressed. The mapping of the trees on the laterite and other places where they were more than ordinarily numerous was done by a modified quadrat system; index trees being previously surveyed with the theodolite. There is still an area in the south-east corner which is incomplete (see map); its similarity to adjacent areas of the gravel slope does not seem to justify the extra work that would be entailed.

The geology and soil-types were next mapped in, the former being determined by outcrops and surface indications.

In order to analyse the shrub vegetation the area was divided into chain-square areas from the centres of which six foot square sample areas were taken. From each of these a composition list was compiled, only annuals and some rare under-shrubs being omitted (5).

The only measurements of habitat factors, apart from those which may be deduced from the survey, were those on the evaporating power of the air.. White Livingston Atmometer Cups were set up in the field; one under the "Jarrah" canopy near the south boundary, and one just above the 650-foot contour near the centre of the south-west boundary (see Plate VIII.). A black cup was also used in conjunction with these to obtain an approximate comparison for the total light received at the two stations.

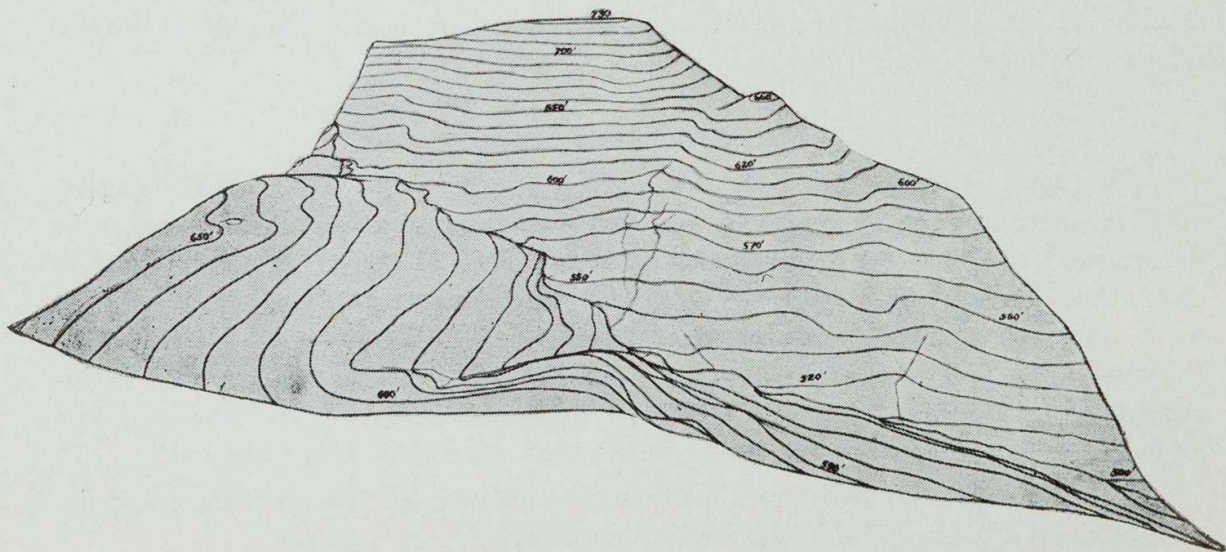
TOPOGRAPHY.*

"The western part," of the "Jarrah" region, "is the dissected western margin of the Great Plateau of Western Australia (Jutson, 1914, p. 19) (3) bounded on the west by the Darling Fault. The topography near the fault-line scarp is somewhat rugged, passing in a distance of five miles or so to the east into the more gently undulating contours of the eastern part of the region." (1, p. 121.)

The Darlington Area "lies in the valley of the Helena River, one of the westerly flowing streams which according to Jutson (1914, p. 128) were consequent on the formation of the Darling Fault, and which, having steeper courses, were able to capture and dismember the senile North-South drainage" (2).

Cohen Brook, which traverses the area from south-east to north-west, is one of the rejuvenated tributaries of the Helena River which "flow in their upper parts through wide shallow valleys in the laterite-covered Darling Peneplain, but on reaching the slopes of the Helena valley they have the same character as the wholly immature tributaries" (2). Beyond the north-west corner of the area Cohen Brook takes a bend and plunges down the steep rejuvenated part of its course.

The topographical details of the area are best seen from the perspective elevation (Text Fig. 1); further description is unnecessary, especially as no detailed work was done on the effect of aspect. In the figure the vertical scale is twice that of the horizontal—the slope angles are therefore accentuated. (N.B.—The absolute elevations were not determined but the approximate figures are given on the figure.)



Text Fig. 1.

Physiographic Perspective Elevation from North Boundary looking South.

Photo., H. Smith.

* See Plate VIII. for detail.

GEOLOGY.*

The Darlington Area is essentially composed of massive granite rocks. They "are traversed by a great number of epidiorite dykes varying in width from a fraction of an inch to a chain or more, and traceable in some instances for more than a mile along their strike." "There is little difficulty in mapping them fairly accurately in the steeper parts of the area; they can in many places be seen outcropping for many chains, and in the intervals their courses are indicated by the abundance of epidiorite boulders, by the dark red soil, and by the predominance of a white-barked eucalypt which contrasts strongly with the dark trunks of the 'Marri' and 'Jarrah' (?)† which predominate on granite" (2).

In only a few places does the Darling Area rise to the "laterite level," which in this region lies between 600 and 700 feet above sea-level.

SOIL-TYPES.*

The soil-types recognised are primarily those in direct relation to and derived from the underlying rock. The author is aware that in many cases such a relation would not necessarily hold good, but superficial examination of the soils in question seemed to indicate its validity on the area studied.

The gravel slide is exceptional but it can scarcely be termed a soil-type. It consists of fragmented laterite which has been washed down over the upper slopes of the valley, thus obscuring the granite and the epidiorite. The amount of gravel varies with the distance from the laterite and the area it covers is best considered to be transitional in nature.

CLIMATIC FACTORS.

The annual rainfall at the nearest meteorological station, Kalamunda, which is two miles south of the area, averages 43 inches. Table 1 gives the mean monthly rainfall, the monthly rainfall from December 1930 to November 1931, and the mean maximum and minimum temperatures over the same period:—

TABLE 1.

Meteorological Information for Kalamunda.

(From *Journal of Agriculture*, W.A.)

Mean Annual Rainfall ... 43·26 inches
December, 1930, to November, 1931 ... 48·95 inches

Rainfall.	Dec., 1930.	Jan., 1931.	Feb., 1931.	Mar., 1931.	Apl., 1931.	May, 1931.	June, 1931.	July, 1931.	Aug., 1931.	Sept., 1931.	Oct., 1931.	Nov., 1931.
Mean monthly...	0·81"	0·55"	0·65"	0·85"	1·89"	6·04"	8·30"	8·45"	6·81"	4·69"	3·15"	1·07"
1930-1931 ...	1·68"	0·00"	0·03"	0·83"	3·60"	7·05"	7·47"	11·1"	7·91"	7·52"	1·70"	0·02"
Temperature—												
Mean maximum	80·5°	87·3°	82·3°	82·7°	73·0°	63·1°	58·2°	57·5°	59·8°	60·7°	70·8°	78·8°
Mean Minimum	56·8°	60·4°	57·5°	60·0°	55·2°	47·8°	43·5°	47·3°	46·3°	46·8°	51·5°	52·6°

Evaporating Power of the Air:—Standardised spherical atmometer cups were set up in the field as stated above for two periods of two weeks. The detailed results appear in Table 2.

* See Plate VIII. for detail. † Question Mark mine.

TABLE 2.

First Period—

Saturday, October 10th to Saturday, October 24th :

Mean maximum temperature ... 77.3

Mean minimum temperature ... 53.2

Second Period—

Saturday, October 31st to Saturday, November 14th :

Mean maximum temperature ... 79.6

Mean minimum temperature ... 54.6

N.B.—A few points more rain and less wind than there were in the first period.

Readings (standardised).

Atmometer.	Period.	Open Marri Con- sociation.	Closed Jarrah Association.
White Bulb	First ...	353 grams	388 grams
	Second...	314 grams	326 grams
Black Bulb	First ...	566 grams	— — —
	Second...	— — —	416 grams
Excess of Black over White Bulb reading	First ...	213 grams	— — —
	Second ...	— — —	90 grams
Approximate ratio of total radiant energy received		7	: 3

Quite unexpectedly it was found that evaporation under the closed "Jarrah" Association was more intense than in the open "Marri" Conso- ciation. This no doubt is to be attributed to the difference in severity of the east winds at the respective stations.

If the excess of the black bulb measurement over that of the white is to be taken as an approximate measure of the radiant energy received at the stations, and if the two periods are considered reasonably comparable, then the ratio for this factor is approximately 7 : 3. Recent research on the light factor in forest ecology suggests that in this case it would be far outweighed by the effect of competition.

It was unfortunate that atmometric readings could not be extended over the entire year. At present there is no basis for comparison either between seasons or with other localities in Western Australia.

VEGETATION.

Two Plant Associations have been recognised on the area studied; the *Eucalyptus calophylla*—*E. redunca* Association which almost exclusively constitutes the valley vegetation of the "Darlington Area," and the *Eucalyptus marginata* Association which dominates the laterite-covered Darling Peneplain. The following descriptions of the Plant Associations and their subdivisions are based almost entirely upon the map (Plate VIII.) and the vegetation analyses (Tables 3 and 4). Discussion of the developmental relations between the communities will be found in a later section of the paper.

It should be emphasised that the description of the *E. marginata* Association here given, only applies to a fringe of the "prime Jarrah forest"

and that it is based on much less evidence than is the description of the *E. calophylla*—*E. redunca* Association. Unfortunately no ecological details of the "prime Jarrah forest" have yet been published.

Eucalyptus calophylla—*E. redunca* Association. (Plate VII., Figs. 1 and 3.)

This Association occupies nearly three-quarters of the area and is characteristic of the soils derived from granite and epidiorite. It also occupies most of the lower parts of the gravel slide. The only associated tree species are *Eucalyptus accedens*, *Nuytsia floribunda*, and *Dryandra floribunda*. The latter, however, is not at all typical of this Association and may possibly have developed after a bush-fire. In another part of Darlington *D. floribunda* has taken possession of a deserted vineyard to the exclusion of almost all other species.

E. calophylla (Marri) and *E. redunca* (Wandoo) are present in approximately equal numbers and form an open woodland, there being on an average four trees to the square chain. *E. accedens* is only represented by one specimen on the area studied; elsewhere it was observed on high ridges and usually associated with *E. marginata*.

Xanthorrhoea Preissii with its peculiar grass-tree habit is characteristic of the Association, there being about 25 and often as many as 40 specimens to a square chain.

The cycad, *Macrozamia Reidlei* is less common, and, though constantly present, apparently favours the moister and shadier localities.

The shrub stratum of the Association has an average height of from one and a half to two feet and is of a markedly sclerophyllous type. The most constant members are *Hibbertia hypericoides*, *Acacia pulchella*, *Hibbertia montana*, and *Dryandra nivea*, and of these the first two constitute co-dominants of the stratum.

Of the larger shrubs (4 to 5 ft.) the following are fairly abundant:—*Hakea cristata*, *Hakea trifurcata*, and *Daviesia horrida*.

In Table 4, in which a full analysis of the shrub vegetation is given, the figures represent constancy, not frequency, and, for comparison, are in each case reduced to a basis in which 10 represents 100 per cent. constancy.

The quadrat (Plate VI., Fig. 3) which is a fairly typical example of the ground vegetation of this Association, indicates the spatial relations of the individual plants of the stratum and also affords a type example of their frequency.

The frequencies of the less common species of the Association as a whole are to a large extent reflected by their constancy figures (Table 4).

Eucalyptus calophylla Consociation.

This characterises soils derived from granite and is also developed in patches along the creek bed, where moisture conditions are better and the soil is deeper. *E. redunca* is occasionally present and a large proportion of the *Nuytsias* are also associated.

Eucalyptus redunca Consociation.

This characterises soils derived from epidiorite, even where the latter is partially obscured by the gravel wash. There are no associated trees.

Dryandra floribunda Society.

This Society occupies about three square chains of very rocky granitic soil towards the west boundary of the area (see map). Its presence is abnormal for the Association and it may have developed after a severe bush-fire.

Nuytsia floribunda can scarcely be said to form definite societies though it occurs in more or less isolated areas. It is usually associated with pure "Marri" or with the mixed "Marri"- "Wandoo" community and occasionally extends into the "Jarrah" Association where the two Associations meet. *Nuytsia* is rarely if ever found as a constituent of the "Wandoo" Consociation and does not upset the space relations of the communities in which it occurs.

With regard to the spacing of the trees within the Association (see Table 3) it should be noticed that the two Consociations are almost the same, namely, three trees per square chain, and that this is considerably less than for the mixed part of the Association which has 4.5 trees per square chain.

Eucalyptus marginata Association. (Plate VII., Fig. 2.)

This Association covers the remainder of the area and characterises the laterite and the upper parts of the gravel slide. Towards the northern boundary there are three small areas (15 square chains in all) which are developed on what is apparently purely granitic soil. The significance of these exceptions will be discussed later.

Associated with the Jarrah (*E. marginata*) in this area, there is a large proportion of *E. calophylla* and *E. redunca*, the percentage being considerably greater than is normal.

Casuarina Fraseriana is the only other tree species found on the area, though *Dryandra floribunda* occurs a little to the south. The distribution of *Nuytsia floribunda* has already been discussed.

The shrub stratum is more scanty than in the other Association and there are spaces between the shrubs which are covered with a litter of leaves. The more important species are—*Bossiaea ornata*, *Grevillea synapheae*, *Hibbertia hypericoides*, *Leschenaultia biloba*, *Hovea chorizemifolia*, and *Dryandra nivea*.

Xanthorrhoea and *Macrozamia* though present, are not so plentiful as in the *E. calophylla*-*E. redunca* Association.

The quadrat (Plate VI., Fig. 1) is typical of the laterite ground vegetation here considered. Although the number of specimens per unit area is comparable with that for the *E. calophylla*-*E. redunca* Association, the individual specimens are on the average only about half the size; hence the comparative scantiness of the covering.

Casuarina Fraseriana Society.

This occupies about three square chains of the lateritic area and is almost a pure stand of "sheoak." Of the 41 trees present only six are eucalypts.

It may be found, as the result of further investigation, that the *E. marginata* Association as developed on the gravel slide is best considered as an ecotone or belt of transition between the *E. marginata* Association on the laterite and the *E. calophylla*-*E. redunca* Association in the valleys. The shrub stratum of the upper parts of the gravel slide was not included in the shrub analysis.

INDICATOR VALUE.

COMMUNITIES.

The correlation between soil and the major plant communities have been stated in the descriptions of the latter. These were primarily based on an extended compass survey and upon general observations throughout the Darlington Area. The correlation between the *E. marginata* Association and soils derived from laterite would certainly be open to question if based solely upon the map (Plate VIII.) but would be undoubted if a vegetation map of the entire Darlington Area were available. Similarly the agreement between the *E. redunca* and *E. calophylla* Consociations and the epidiorite and granite respectively was confirmed and emphasised by the extended observations.

TREE SPECIES.

Turning now to the consideration of the individual tree species it is found that the correlation with soil type is not nearly so precise as that for the communities. The following specific statements are based on Table 3.

Eucalyptus calophylla, R.Br.

The "Marri," locally called "Red Gum," is present on all the soil types. On granite it constitutes 60 per cent. of the Eucalypts and on the gravel slide it shares the dominance with *E. redunca*, the two species being present in equal numbers. On epidiorite and laterite *E. calophylla* is subordinate to the other Eucalypts.

The percentages shown opposite "Gravel slide over granite" and "Gravel slide over epidiorite" are for those portions of the gravel slide which do not support the *E. marginata* Association. The figures show that the correlation is not destroyed by the presence of the gravel.

Eucalyptus redunca, Schau. var. *elata*.

The "Wandoo," erroneously called "White Gum," is dominant on epidiorite (70 per cent.), co-dominant with *E. calophylla* on the gravel slide (37 per cent.), and subordinate on granite and laterite.

Eucalyptus marginata, Sm.

The "Jarrah" tree dominates the laterite (79 per cent.), is very frequent on the gravel slide (26 per cent.), and is normally absent from granite and epidiorite. The high percentage (26 per cent.) here found on granite is due to the presence of the abnormal remnants of the *E. marginata* Association.

Nuytsia floribunda (Labill.), R.Br.

This species is, on the area studied, confined to granite and the lower parts of the gravel slide. As yet the author has not seen a specimen on laterite or on any purely epidioritic soils.

Casuarina Fraseriana, Miq.

This "Sheoak" is, in the Darlington Area, definitely confined to laterite.

Dryandra floribunda, R.Br.

This species, though present on granite on the area studied, is normally found on laterite. Given the chance, it rapidly colonises abandoned cultivations and severely burnt areas, irrespective, it would seem, of the soil type.

Xanthorrhoea Preissii Endl. and *Macrozamia Reidlei* (Gaud.) Gardner are present on all the soil types. Nothing definite can as yet be said as to the causes of their variable frequency from place to place.

SHRUB SPECIES.

The details of the shrub analysis appear in Table 4, and are based on 197 sample areas obtained as described under Methods of Work. The number of samples for granite (66), epidiorite (35), and laterite (20) are

as complete as the area would permit. In the case of the gravel slide it was decided to analyse a limited number only, as the area covered by this is proportionally greater than is the case for the Darlington Area as a whole. The upper portion of the gravel slide, which more or less coincides with the transition between the laterite and valley vegetation, was entirely omitted from the analysis.

In taking the samples, areas which were obviously developmental were omitted, and in order to eliminate some late seral stages which were unavoidably included, the whole series was subjected to an analysis based on the dominant and highly constant species. First the composition lists were arranged in groups each possessing the same constant species. For instance in one group *Acacia pulchella*, *Hibbertia hypericoides* and *Dryandra nivea* were present and *Hibbertia montana* absent; in another *Acacia pulchella* and *Dryandra nivea* were absent and the two *Hibbertias* were present. The constancy figures for all these groups were then compared with those for the whole Association. By this means, those groups which lacked either or both of the dominants, and showed other marked divergence from the average type, were discarded from the final analysis. It was soon seen that there were no fundamental distinctions between the shrub stratum covering the granite, epidiorite, or lower parts of the gravel slide. In other words, the dominants were the same and the more constant species showed almost equal constancy in each case.

In the shrub analysis table, column "A" is obtained by the summation of columns "D," "E," and "F." Column "A" is therefore, for the area studied, a fairly accurate analysis of the shrub stratum of the *E. calophylla*—*E. redunca* Association. For comparative purposes the figures are reduced to a basis of ten, and in this instance are expressed to the first decimal place.

Column "C" affords the striking contrast which might be expected between the shrub vegetation of the two Associations (compare columns "A" and "C"). Column "B" represents the ground vegetation of the *E. marginata* Association as developed on granite and shows a composition intermediate between the two normal Associations.

The following classification of the shrub species is based directly on Table 4, and presents the main features of the Table in a more lucid form.

1. Species whose constancies are approximately equal for granite, epidiorite, gravel slide, and laterite.

<i>Dryandra nivea</i>	<i>Hibbertia hypericoides</i>
<i>Hovea trisperma</i>	<i>Hibbertia montana</i>
<i>Hakea bipinnatifida</i>	<i>Olearia paucidentata</i>
<i>Sphaerolobium medium</i>	<i>Gompholobium marginatum</i> ?

*Probably overlooked on gravel (see Table).

2. Species whose constancies are approximately equal for granite, epidiorite, and gravel slide, but which are absent from or relatively rare on laterite.

<i>Acacia pulchella</i>	<i>Leucopogon sprengelioides</i>
<i>Grevillea pilulifera</i>	<i>Hypocalymma angustifolia</i>
<i>Hakea undulata</i>	<i>Casuarina humilis</i>
<i>Hakea trifurcata</i>	<i>Daviesia polyphylla</i>
<i>Andersonia sprengelioides</i>	<i>Bossiaea biloba</i>
<i>Thomasia glutinosa</i>	<i>Daviesia horrida</i>
<i>Hibbertia polystachya</i>	<i>Astroloma pallidum</i> *
<i>Baeckea camphorosmae</i> *	

*Rare on laterite.

3. Species whose constancies indicate that they are practically confined to granite.

Dryandra armata
Hakea stenocarpa

Gompholobium polymorphum

4. Species whose constancies indicate a more or less marked preference for granite as opposed to epidiorite. Constancies various on gravel slide—absent from laterite.

Synaphaea acutiloba
Eriostemon spicatum
Gastrolobium epacridioides
Pultenaea ericifolia

Melaleuca scabra
Hakea incrassata
Chorizema Dicksonii
*Petropohila striata**

*Also on laterite.

5. Species whose constancies indicate a more or less marked preference for epidiorite as opposed to granite; absent from laterite.

Daviesia brevifolia
Hakea erinacea
Isopogon asper
Synaphaea pinnata

Petrophila seminuda
Phyllanthus calycinus
Trymalium ledifolium
Acacia decipiens

6. Species confined to laterite (excluding the remnant of *E. marginata* Association on granite).

Bossiaea ornata
Grevillea synapheae
Adenanthos barbigera
Hibbertia pachyrrhiza
Kennedya coccinea
Hovea chorizemifolia

Leschenaultia biloba
Conostylis setigera var. *discolor*.
Isopogon sphaerocephalus
Styphelia tenuiflora

N.B.—Some of these species may occur on the upper parts of the gravel slide.

7. Species whose constancies indicate a preference for laterite.

Synaphaea petiolaris
Dampiera linearis

Daviesia pectinata

8. Species whose constancies indicate a preference for gravel.

Oxylobium cuneatum
Dampiera alata

Dillwynia cinerascens.

9. Species whose constancies are equal for granite and epidiorite—absent or infrequent on gravel and laterite.

Pimelea rosea
*Tetratheca hirsuta**

Grevillea bipinnatifida

*Assuming the form of *T. hirsuta* found on laterite to be a distinct variety.

The two species *Hypocalymma robusta* and *Hakea cristata* show high constancies for the abnormal *E. marginata* Association on granite and for the area studied, are practically limited to it. Elsewhere in the Darlington Area *Hypocalymma robusta* has been observed most frequently on gravel slides. *Hakea cristata* on the other hand appears abundantly on granite and epidiorite as a colonist after severe bushfires. Both these species, therefore, would seem to support the theory that these remnants of the *E. marginata* Association are gradually giving way to the *E. calophylla*-*E. redunca* Association.

In concluding it is important to notice that for the *E. calophylla*—*E. redunca* Association all species having constancies of 3.2 and over fall within groups 1 and 2 of the classification, while, with the exception of *Melaleuca scabra*, no species with any pretence to indicator value has a constancy of more than three, even for its favourable habitat. *Melaleuca scabra* has a constancy of 5 on granite as against 3.1 for the Association as a whole.

Shrub stratum indicators of the underlying bedrock of the hill slopes are therefore practically wanting. It does not follow, however, that under more favourable conditions of slope and aspect, no such indicators could be found. From extended observation, for instance, the author is convinced that *Hakea myrtoides*, Meissn., is a fairly accurate indicator of epidioritic soils.

DISCUSSION.

The present investigation has suggested the possibility of throwing light on the origin of the valley vegetation. Assuming Jutson's Peneplanation theory (3) to be the correct key to the interpretation of the physiography

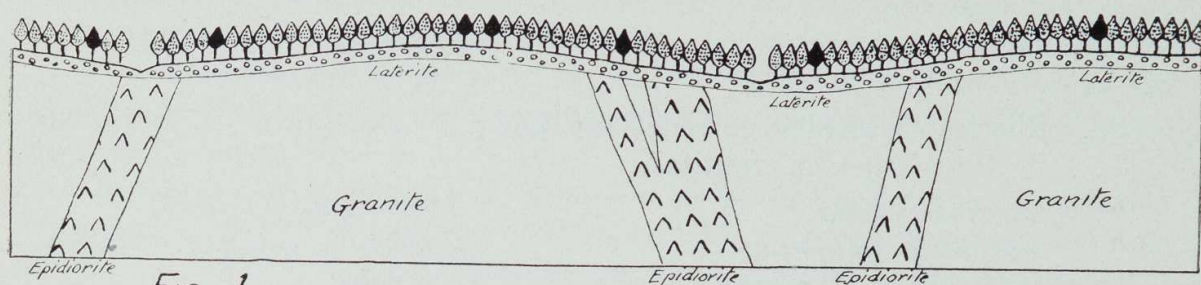


Fig. 1.

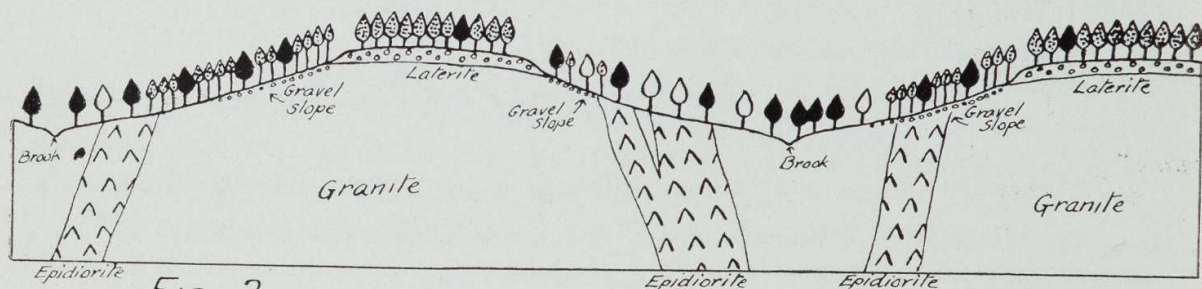


Fig. 2.

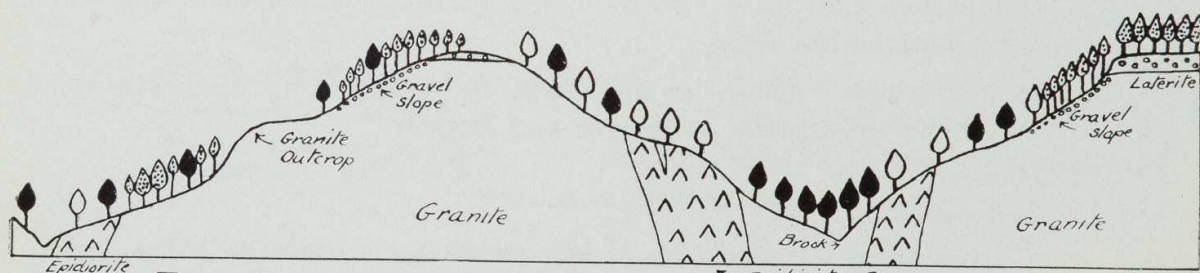






Fig. 3.

- | | |
|---|--|
|  <i>E. marginata</i> |  <i>E. calophylla</i> |
|  "do" saplings |  <i>E. redunca</i> |

Diagrams showing successive stages in valley formation and their attendant vegetational changes.

Text Fig. 2.

of the region, it is probable that the *E. marginata* Association originally covered the whole area (Text Fig. 2, Fig. 1). As the plateau became dissected by watercourses the "Jarrah" Association would be locally destroyed by the progressive breaking away of the laterite capping. At first the gravelly slopes produced in the process could only be colonised by the con-

stituent species of the *E. marginata* Association, but as the valleys widened and deepened it would be possible for species from other Associations to immigrate and take possession of portions of the "Jarrah" region (e.g., *E. rudis*, "Flooded Gum" Association along the larger watercourses).

The composition of the *E. marginata* Association that would have developed on the gravel slopes may be assumed to have been similar to the one developed on the area studied. Here *E. calophylla* and *E. redunca* show marked increases in frequency as compared with the *E. marginata* as developed on laterite. *E. marginata* itself, though still dominant, is of course correspondingly reduced in proportional frequency (see tree analysis).

As valley formation continued, the soils of the lower slopes would be produced more from the bedrock and less from transported fragments of laterite. This fact, together with changed water relations and the different powers possessed by the three Eucalypts concerned to reproduce by seed, seems sufficient to explain the replacement of the *E. marginata* Association by the *E. calophylla*-*E. redunca* Association. (Text Fig. 2, Fig. 2.)

At the present time there exist extensive areas, of which the Helena River Valley is one, over which the laterite covering has been entirely removed and in which gravelly slopes are relatively insignificant. Here the soils are derived from granite and epidiorite and the two types conform for the most part with the distribution of the parent rocks. For reasons as yet unknown *E. redunca* has been able to maintain itself on epidioritic soils but has failed on granitic soils. Similarly *E. calophylla* has been successful on granitic soils and not on those derived from epidiorite. (Text Fig. 2, Fig. 3.)

The above theory therefore suggests that the *E. calophylla*-*E. redunca* Association has been derived directly from the *E. marginata* Association and that the Consociations of its component species are produced by segregation in response to local differences in the total environment.

In support of the above, attention is drawn to the third section of the tree analysis. The spacing for the *E. marginata* Association on gravel is 8.8 and of this community 40 per cent. of the trees are *E. calophylla* and *E. redunca*. If all the "Jarrah" were removed, an artificial *E. calophylla*-*E. redunca* Association would remain with a spacing of 3.5 trees per square chain. Allowing for regeneration it will be seen that this figure would tend to approach the figure for the natural mixed Association (4.5).

Again, for the mixed *E. calophylla*-*E. redunca* Association the number of Eucalypts per square chain is 4.5, while for the Consociations the number is about 3.0 in each case. It will be seen that the *E. redunca* Consociation could be artificially produced from the mixed Association by removing *E. calophylla* and allowing *E. redunca* to regenerate to a limited extent. The *E. calophylla* Consociation would of course be produced by the reverse process.

The space relations, therefore, of the Communities in question are in harmony with the theory and in being so lend definite support to it.

The following facts, deduced from an extended survey by compass and pacing and which was undertaken after the main field work for the present paper had been completed, indicate that the distribution of the communities is also in accord with the theory:—

1. The mixed *E. calophylla*-*E. redunca* community, though extensive, is rarely found below the 500' contour line, and its upper limit usually passes into the *E. marginata* Association.
2. The bulk of the *E. calophylla* and *E. redunca* Consociations occur below the 550' contour and they are rarely in direct contact with the *E. marginata* Association, except perhaps in very steep places. (See map.)

3. Below 500' the agreement between the Consociations and their respective soil-types is even more striking and pronounced than it is on the area here described.

There still remains for explanation the abnormal development of *E. marginata* on what is apparently pure granitic soil. Of the three areas shown, the two smaller ones actually occur on the edge of the gravel slide, and one of them continues northward into a considerable area of typical *E. marginata* Association on gravel. This area is over 600 feet above sea-level and occupies the western side of a hill from which laterite has almost completely been removed (see Text Fig. 2, Fig. 3). The whole slope is fairly well protected from the desiccating east winds, as is demonstrated by the complete absence of *E. marginata* from the eastern slopes of the hill. The western slope must originally have had a continuous clothing of *E. marginata* saplings (Text Fig. 2, Fig. 2), but subsequent to the rejuvenation of Cohen Brook (see topographical section), rapid erosion left a large granite outcrop exposed half-way down the slope. Exceptionally favourable circumstances, therefore, have made it possible for *E. marginata* to maintain itself on this lower slope below the outcrop and have allowed the development of some relatively large specimens of "Jarrah." *E. calophylla*, however, is represented by the largest trees, and it seems probable that the community will eventually give place to the *E. calophylla* Consociation.

CONCLUSION.

With reference to indicator value the following conclusions may be stated for the area studied:—

1. The plant communities are fairly precise indicators of the soil-types.
2. The tree species, when taken separately, are poor indicators of soil-type.
3. The indicator value of shrub species for the two soil-types of the valley is negligible, and the sharp distinction between lateritic and valley shrub species is probably due more to community relations than to soil differences.

It seems probable that the "predominance of a white-barked eucalypt" used by E. de C. Clarke and F. A. Williams (2) is coincident with the *E. redunca* Consociation here described. If so, the present paper definitely affirms its observed relation with the Epidiorite dykes.

SUMMARY.

The predominant Association of the valley vegetation of part of the Darlington Area has been analysed, described, and compared with the adjacent vegetation of the plateau.

The indicator value of plant communities, trees, and shrubs was investigated and a tentative theory has been advanced to explain the origin of the *E. calophylla*-*E. redunca* Association and its Consociations.

In closing I desire to express my sincere thanks to Mrs. E. R. L. Johnson for constant advice and for constructive criticism during the preparation of the present paper. To Professor E. de C. Clarke and the Department of Geology I am indebted for the use of surveying instruments and of their Draughting Room. I also desire to thank all fellow students and friends who assisted with the field work.

The Government Botanist, Mr. C. A. Gardner, has carefully checked my identifications of the species mentioned in the paper, and all specific names refer to his Census of Western Australian Plants (6).

TABLE 3.

TREE ANALYSIS.

Total No. of Trees—1,825.

Total No. of Eucalypts—1,687.

Area—440 sq. chns.

Part 1.		Eucalyptus calophylla, R.Br.	E. redunca, Schau. var. elata.	Eucalyptus marginata, Sm.	Nuytsia floribunda (Labill).	Casuarina Fraseriana, Miq.	Totals.
Communities.							
E. calophylla-E. redunca Association.							
a. Excluding Consociations	No. ... % Eucalypts	303 61	197 39	1 —	24 —	— —	525
b. E. calophylla Consociation	No. ... % Eucalypts	192 97	5 3	— —	44 —	— —	241
c. E. redunca Consociation	No. ... % Eucalypts	2 1	295 99	— —	— —	— —	297
d. Entire Association	No. ... Per cent. % Eucalypts	497 47 50	497 47 50	1 — —	68 6 —	— — —	1063
E. marginata Association							
e. On Laterite excluding Casuarina Society	No. ... % Eucalypts	18 14	9 7	101 79	— —	14 —	142
f. On Gravel slide ...	No. ... % Eucalypts	85 25	54 16	206 59	14 —	— —	359
g. On Granite ...	No. ... % Eucalypts	73 34	11 5	129 61	7 —	— —	220
h. Casuarina Society...	No. ...	1	1	4	—	35	41
j. Entire Association ...	No. ... % Eucalypts	177 26	75 11	440 63	21 —	49 —	762
Totals ...		674	572	441	89	49	1825
Part 2.							
Soil Types (Indicator Value).							
Granite ...	No. ... % Eucalypts	277 60	65 14	122 26	52 —	— —	516
Epidiorite ...	No. ... % Eucalypts	74 28	192 71	3 1	— —	— —	269
Gravel slide ...	No. ... % Eucalypts	304 37	305 37	211 26	37 —	— —	857
Gravel slide— 1. over granite ...	% Eucalypts	70	30	—	—	—	
2. over epidiorite...	% Eucalypts	16	84	—	—	—	
Laterite ...	No. ... % Eucalpyts	19 14	10 7	105 79	— —	49 —	183
Totals ...		674	572	441	89	49	1825

TABLE 3—continued.

TREE ANALYSIS—continued.

Part 3.	No. of	Area in	No. per
Space Relations	Eucalypts.	Sq. Chains.	Sq. Chain.
Community			
E. calophylla — E. redunca Association :			
a. Excluding Consociations	501	112	4.5
b. E. calophylla Consociation	197	71	2.8
c. E. redunca Consociation	297	94	3.2
d. Entire Association	995	277	3.6
E. marginata Association :			
e. On Laterite excluding Casuarina Society	128	16	8.0
f. On Gravel slide	345	41	8.4
g. On Granite	213	15	14.2
h. Casuarina Society	6	3	2.0
j. Entire Association	692	75	9.2
Seral Areas	35	
Not Mapped	53	
Totals	1,687	440	

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3. Jutson, J. T., "An Outline of the Physiographical Geology of Western Australia," Geological Survey of W.A. Bulletin No. 61. (1914.)

4. Gardner, C. A., "The Salient Features of the Plant Geography of Extra-tropical Western Australia." Handbook of Science in W.A., 18th Meeting A.A.A.S. (1926.)

5. Smith, W. G., "Raunkiaer's Life Forms and Statistical Methods." Journal of Ecology, Vol. I., p. 16 (1913).

6. Gardner, C. A., "Enumeratio Plantarum Australiae Occidentalis."

TABLE 4.

SHRUB ANALYSIS.

"A" E. calophylla - E. redunca Association

"B" E. marginata Association on granite.

"C" Laterite.

"D" Gravel slide.

"E" Granite.

"F" Epidiorite.

Species.	"A."		"B."		"C."		"D."		"E."		"F."	
	No. of Samples ...	157	10	20	10	20	10	56	10	66	10	35	10
Acacia pulchella, R. Br. ...	137	8.8	17	8.5	...	...	47	8.5	63	9.5	27	8
Acacia decipiens, R. Br. ...	5	0.3	...	...	...	...	1	—	...	...	4	1
Adenanthos barbigera, Lindl. ...	...	...	...	...	4	2	...	...	...	...	...	...
Andersonia sprengelioides, R. Br. ...	56	3.5	...	...	...	...	20	3.5	30	4.5	6	2
Astroloma pallidum, R. Br. ...	56	3.5	3	1.5	2	1	18	3	21	3	17	5
Baeckea camphorosmae, Endl. ...	77	4.9	3	1.5	1	0.5	30	5.5	27	4	20	5.5
Bossiaea biloba, Benth. ...	58	3.7	...	...	...	...	16	3	28	4	14	4
Bossiaea, ornata (Lindl.) ...	...	...	5	2.5	19	9.5	...	...	...	...	...	...
Casuarina humilis, Otto et Dietr. ...	26	1.6	...	...	...	...	13	2.5	8	1	5	1.5
Chorizema Dicksonii, Grah. ...	24	1.5	2	1	...	...	5	1	16	2.5	3	1
Conostylis setigera, R. Br., var. discolor ...	...	...	...	...	11	5.5	...	...	...	...	...	...
Dampiera linearis, R. Br. ...	24	1.5	14	7	13	6.5	13	2.5	11	1.5	...	...
Dampiera alata, Lindl. ...	17	1.0	10	5	...	...	10	2	4	0.5	3	1
Daviesia brevifolia, Lindl. ...	10	0.6	...	...	...	...	1	—	4	0.5	5	1.5
Daviesia horrida, Meissn. ...	9	0.5	...	...	...	...	3	0.5	3	0.5	3	1
Daviesia pectinata, Lindl. ...	16	1.0	4	2	15	7.5	11	2	3	0.5	2	0.5
Daviesia polyphylla, Benth. ...	27	1.7	...	...	...	...	12	2	11	1.5	4	1
Dillwynia cinerascens, R. Br. ...	15	1.0	...	...	...	...	7	1.5	6	1	2	0.5
Dryandra armata, R. Br. ...	19	1.2	...	...	...	...	...	...	19	3	...	...
Dryandra nivea, R. Br. ...	116	7.4	17	8.5	15	7.5	46	8	44	6.5	26	7.5
Eriostemon spicatum, A. Rich. ...	31	2.0	8	4	...	...	10	2	17	2.5	4	1
Gastrolobium epacridioides, Meissn. ...	26	1.6	...	...	...	...	13	2.5	13	2	...	...
Gompholobium marginatum, R. Br. ...	19	1.2	1	0.5	5	2.5	1	(?)	9	1.5	9	2.5
Gompholobium polymorphum, R. Br. ...	12	0.8	1	0.5	...	...	...	...	12	2	...	...
Grevillea bipinnatifida, R. Br. ...	10	0.6	...	...	...	...	1	—	6	1	3	1
Grevillea pilulifera (Lindl.) ...	81	5.1	6	3	...	...	23	4	35	5.5	23	6.5
Grevillea synapheae, R. Br. ...	...	...	...	...	13	6.5	...	...	...	...	...	...
Hakea bipinnatifida, R. Br. ...	72	4.5	5	2.5	11	5.5	30	5.5	19	3	23	6.5
Hakea cristata, R. Br. ...	2	0.1	11	5.5	...	...	...	...	...	...	2	0.5
Hakea erinacea, Meissn. ...	17	1.0	...	...	...	...	4	0.5	4	0.5	9	2.5
Hakea incrassata, R. Br. ...	25	1.5	...	...	...	...	2	0.5	20	3	3	1
Hakea stenocarpa, R. Br. ...	14	0.9	2	1	...	...	1	—	13	2	...	...
Hakea trifurcata (Sm.) ...	34	2.2	...	...	...	...	17	3	8	1	9	2.5
Hakea undulata, R. Br. ...	69	4.4	9	4.5	...	...	24	4.5	33	5	12	3.5
Hibbertia hypericoides (D.C.) ...	150	9.5	20	10	20	10	54	9.5	64	9.5	32	9.5
Hibbertia montana, Steud. ...	121	7.7	8	4	16	8	43	7.5	49	7.5	29	8.5
Hibbertia pachyrrhiza, Steud. ...	...	...	...	...	7	3.5	...	...	...	...	...	...
Hibbertia polystachya, Benth. ...	31	2.0	...	...	...	...	7	1.5	13	2	11	3
Hovea chorizemifolia (Sweet) ...	1	0.1	2	1	14	7	1	—	...	...	...	...
Hovea trisperma, Benth. var. crispa	71	4.5	16	8	7	3.5	23	4	35	5.5	13	3.5
Hypocalymma angustifolia, Endl. ...	78	5.0	3	1.5	...	...	23	4	32	5	23	6.5
Hypocalymma robusta, Endl. ...	...	...	19	9.5	...	...	...	...	...	...	...	...
Isopogon asper, R. Br. ...	32	2.1	1	0.5	...	...	16	3	6	1	11	3
Isopogon sphaerocephalus, Lindl. ...	...	...	...	...	8	4	...	...	...	...	...	...
Kennedya coccinea, Vent. ...	...	...	4	2	5	2.5	...	...	...	...	...	...
Leucopogon sprengelioides, Sond. ...	97	6.2	2	1	...	...	30	5.5	46	7	21	6
Leschenaultia biloba, Lindl. ...	1	0.1	1	0.5	10	5	1	—	...	...	...	...
Melaleuca scabra, R. Br. ...	49	3.1	...	...	...	...	10	2	34	5	5	1.5
Olearia paucidentata, (Steetz.) ...	26	1.6	4	2	4	2	9	1.5	11	1.5	6	2
Oxylobium cuneatum, Benth. ...	15	1.0	8	4	...	...	13	2.5	2	0.5	...	...
Petrophila seminuda, Lindl. ...	11	0.7	...	...	...	...	3	0.5	2	0.5	6	2
Petrophila striata, R. Br. ...	21	1.8	...	...	3	1.5	9	1.5	12	2	...	...
Phyllanthus calycinus, Labill. ...	12	0.8	2	1	...	...	2	0.5	2	0.5	8	2.5
Pimelea rosea, R. Br. ...	24	1.5	14	7	...	...	...	...	14	2	10	3
Pultenaea ericifolia, Benth. ...	12	0.8	...	...	...	...	3	0.5	9	1.5	...	...
Sphaerolobium medium, R. Br. ...	50	3.2	16	8	7	3.5	8	1.5	31	4.5	11	3
Styphelia tenuiflora, Lindl. ...	...	...	...	...	5	2.5	...	...	...	...	...	...
Synaphaea acutifolia, Meissn. ...	31	2.0	...	...	...	...	10	2	19	2	2	0.5
Synaphaea petiolaris, R. Br. ...	27	1.7	6	3	14	7	12	2	8	1	7	2
Synaphaea pinnata, Lindl. ...	18	1.1	...	...	...	...	5	1	2	0.5	11	3
Tetratheca hirsuta, Lindl. ...	36	2.3	3	1.5	(6	3)*	2	0.5	21	3	13	3.5
Thomasia glutinosa, Lindl. ...	22	1.4	2	1	...	...	7	1.5	9	1.5	6	2
Trymalium ledifolium, Fenzl. ...	10	0.6	...	...	...	...	...	...	2	0.5	8	2.5

* Possibly a distinct variety of T. hirsuta.

INDEX TO QUADRAT CHARTS (PLATE VI.).

E. marginata Association (Fig. 1).

Total number of specimens 261.

B.	Bossiaea ornata (Lindl.)	...	103	I.	Isopogon sphaerocephalus,		
L.	Leschenaultia biloba, Lindl.	...	19		Lindl.	...	4
G.	Grevillea synapheae, R. Br.	...	13	O.	Olearia paucidentata (Steetz)	...	4
Al.	Astroloma longiflorum	...	13	Hp.	Hibbertia pachyrrhiza, Steud.		2
H.	Hibbertia hypericoides (D.C.)		12	Td.	Thysanotus dichotomus (Labill)		2
Ho.	Hovea chorizemifolia (Sweet)	...	11	A.	Adenanthos barbigera, Lindl.		2
D.	Dryandra nivea, R. Br.	...	11	Lo.	Lomandra Endlicheri (F. v. M.)		2
Sh.	Stylidium hispidum, Lindl. *	...	10	S.	Synaphea petiolaris, R. Br.	...	1
Da.	Dampiera linearis, R. Br.	...	10	Lp.	Leucopogon propinquus, R. Br.		1
C.	Conostylis setigera, R. Br. v.			La.	Labichea punctata, Benth.	...	1
	discolor	...	8	P.	Petrophila striata, R. Br.	...	1
T.	Tetradlea hirsuta, Lindl.	...	8	Sm.	Sphaerolobium medium, R. Br.		1
St.	Styphelia tenuiflora, Lindl.	...	8	Gp.	Gompholobium Preissii, Meissn.		1
Hb.	Hakea bipinnatifida, R. Br.	...	7	X.	Xanthosia peltigera (Hook.)	...	1
Dp.	Daviesia pectinata, Lindl.	...	5				

E. calophylla—E. redunca Association (subseral area after repeated bush-fires (Fig. 2).

Total number of specimens 67.

A.	Acacia pulchella, R. Br.	...	31	Ht.	Hakea trifurcata (Sm.)	...	3
Hy.	Hypocalymma angustifolium,			Gs.	Gastrolobium spathulatum,		
	Endl.	...	12		Benth.	...	2
D.	Dryandra nivea, R. Br.	...	9	Hc.	Hakea cristata, R. Br.	...	2
H.	Hibbertia hypericoides (D.C.)		3	L.	Leucopogon sprengelioides,		
S.	Sedge (unidentified)	...	4		Sond.	...	1

E. calophylla—E. redunca Association (Fig. 3).

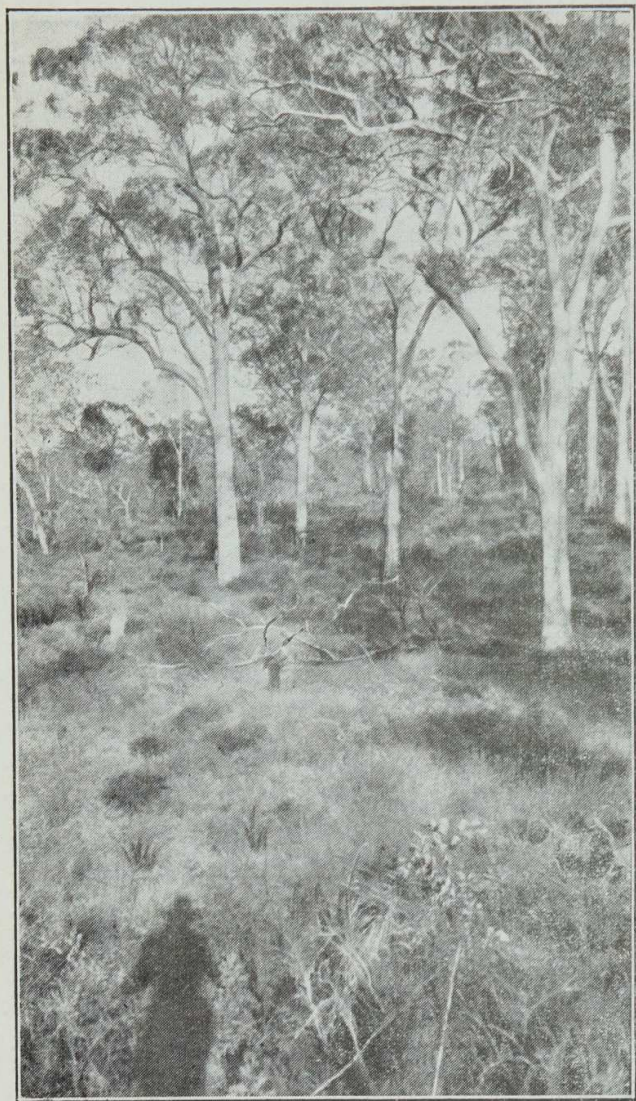
Total number of specimens 326.

A.	Acacia pulchella, R. Br.	...	73	Gp.	Grevillea pilulifera (Lindl.)	...	5
H.	Hibbertia hypericoides (D.C.)		62	O.	Olearia paucidentata (Steetz)		5
S.	Sphaerolobium medium, R. Br.		25	Ap.	Astroloma pallidum, R. Br.	...	4
Ho.	Hovea trisperma, Benth. v.			Bc.	Baeckea camphorosmae, Endl.		4
	crispa	...	22	C.	Casuarina humilis, Otto et		
Hm.	Hibbertia montana, Steud.	...	21		Dietr.	...	4
As.	Andersonia sprengelioides, R.			P.	Petrophila striata, R. Br.	...	4
	Br.	...	18	I.	Isopogon asper, R. Br.	...	3
Hb.	Hakea bipinnatifida, R. Br.	...	17	Dp.	Daviesia pectinata, Lindl.	...	3
D.	Dryandra nivea, R. Br.	...	11	Ox.	Oxylobium cuneatum, Benth.		3
B.	Bossiaea biloba, Benth.	...	8	Hu.	Hakea undulata, R. Br.	...	2
Cd.	Chorizema Dicksonii, Grah.	...	6	M.	Mesomelaena tetragona (R.		
G.	Gompholobium marginatum,				Br.) *	...	2
	R. Br.	...	6	Sp.	Synaphea petiolaris, R. Br.	...	2
L.	Leucopogon sprengelioides,			Hs.	Hakea stenocarpa, R. Br.	...	2
	Sond.	...	6	X.	Xanthorrhoea Preissii, Endl.	...	1
Hy.	Hypocalymma angustifolium,			Da.	Dampiera linearis, R. Br.	...	1
	Endl.	...	6				

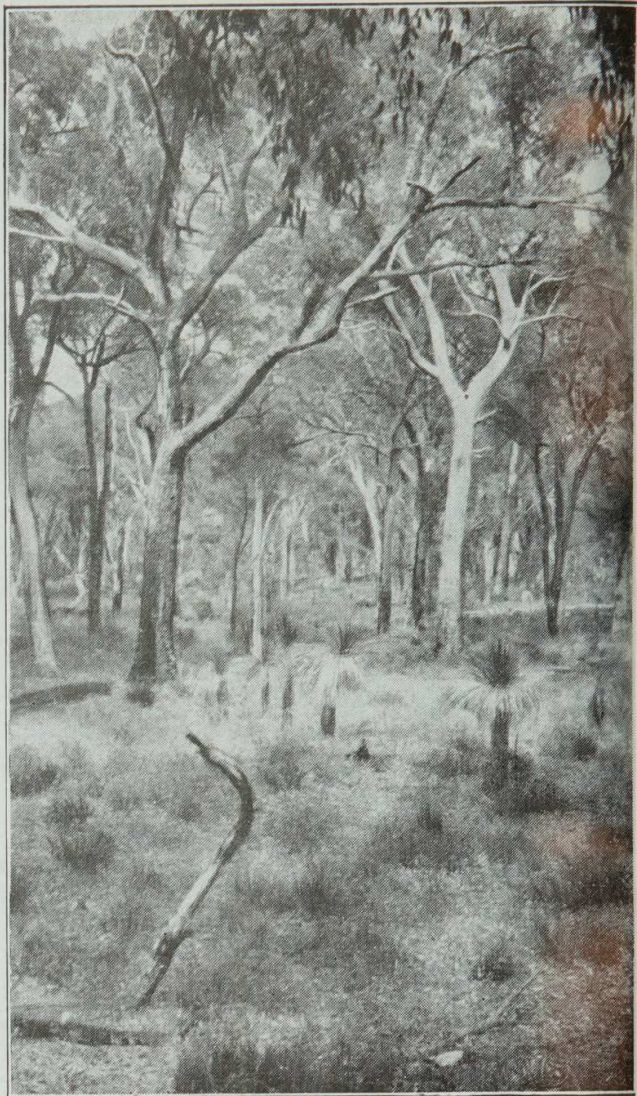
* Identification doubtful.

N.B.—The areas bounded by dotted lines indicate the extent of lateral spread of the larger undershrubs. Similarly the radiating lines around X. and M. in Fig. 3 show the extent of the radiating leaves of a young "Blackboy" and of a sedge.

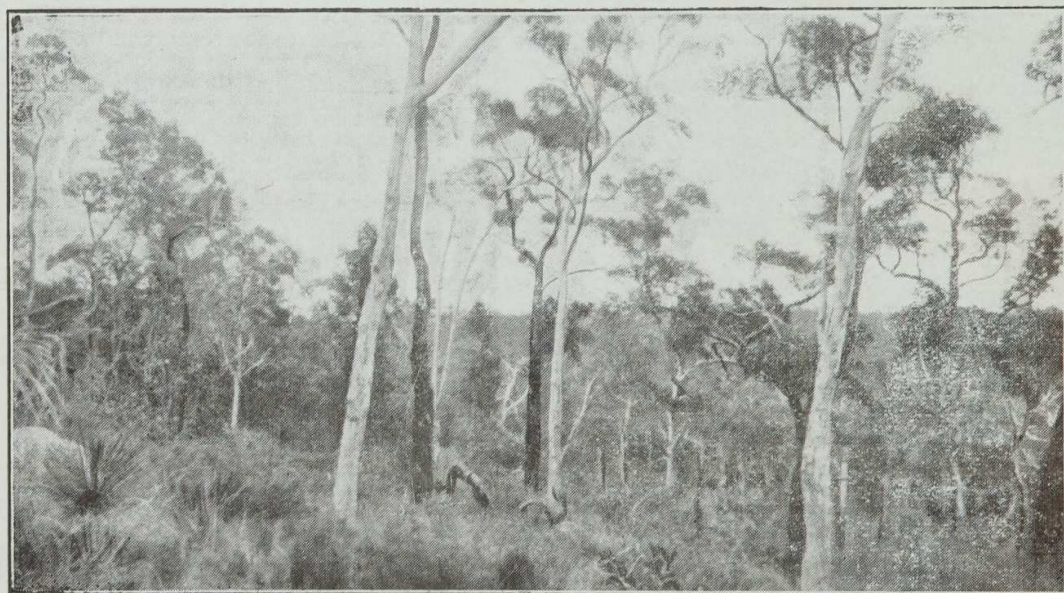
PLATE VII.



E. redunca Consociation on gravel
slide.
Fig. 1.

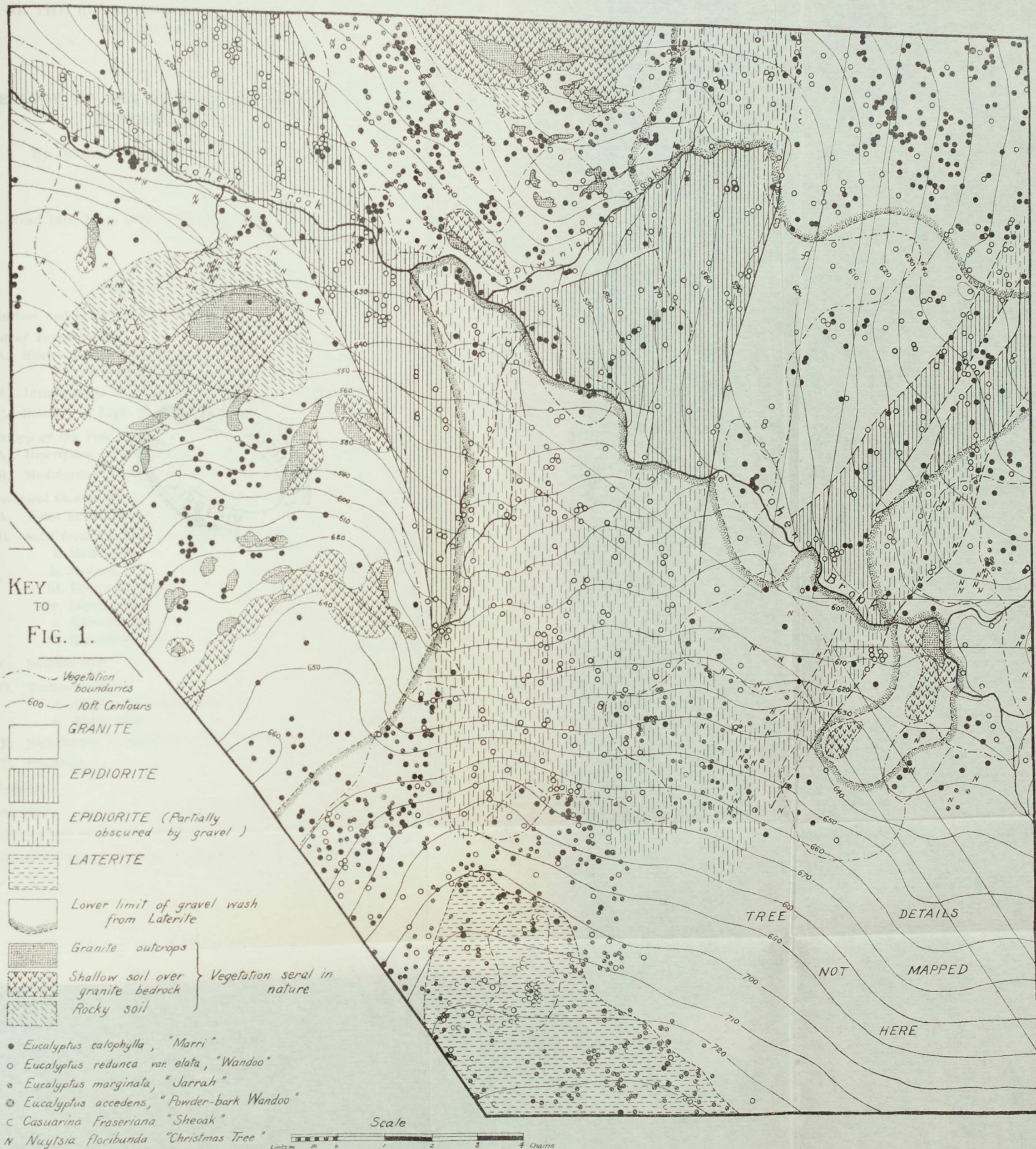


E. marginata Association on laterite.
N.B.—Scanty shrub-stratum and leaf litter.
Fig. 2.



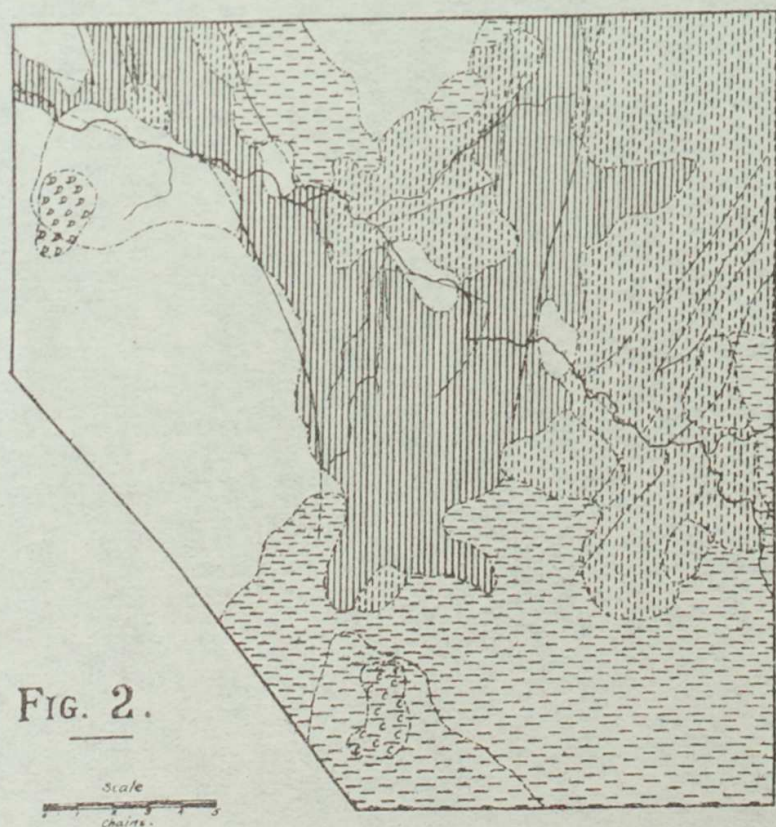
E. calophylla-*E. redunca* Association on Granite.
Fig. 3.





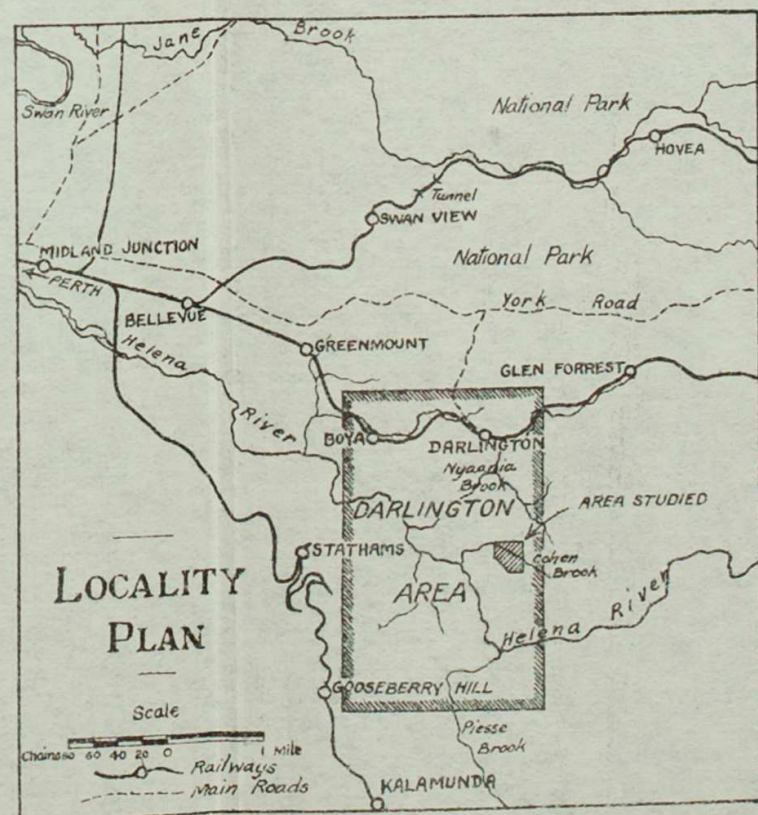
— FIG. 1. —

SHOWING TREES, GEOLOGY,
 SOIL-TYPES, AND
 PHYSIOGRAPHY.



KEY TO PLANT COMMUNITIES
 Fig. 2.

- ▨ *E. calophylla* - *E. redunca* (mixed) Association
- ▨ *E. redunca* Consociation
- ▨ *E. calophylla* Consociation
- ▨ *E. marginata* Association
- ▨ *Casuarina Fraseriana* Society
- ▨ *Dryandra floribunda* Society



VEGETATION MAP OF AN AREA NEAR DARLINGTON, WESTERN AUSTRALIA.

